Adaptive Combinatorial Multimodal Sensing Physics & Methods

7 Mar 2012

Dr. Kitt Reinhardt
Program Manager
AFOSR/RSE
Air Force Research Laboratory

Integrity ★ Service ★ Excellence

DISTRIBUTION A: Approved for public release; distribution is unlimited.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **07 MAR 2012**	2. REPORT TYPE	3. DATES COVERED **00-00-2012 to 00-00-2012**

4. TITLE AND SUBTITLE **Adaptive Combinatorial Multimodal Sensing Physics & Methods**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Air Force Research Laboratory,Wright Patterson Air Force Base,OH,45433**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Presented at the Air Force Office of Scientific Research (AFOSR) Spring Review Arlington, VA 5 through 9 March, 2012

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**27**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Vision

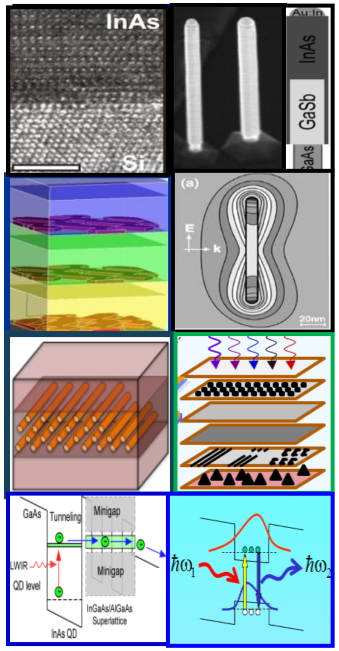
Accelerate & exploit discovery of novel solid-state materials science, nano/microstructure device physics, and implementation schemes for future breakthrough-generations of adaptive, intelligent, compact and affordable combinatorial-multimodal sensing and exploitation methods enabling for game-changing adaptive & autonomous ISR.

2012 AFOSR SPRING REVIEW

NAME: **Kitt Reinhardt**

BRIEF DESCRIPTION OF PORTFOLIO: **Multimodal Sensing Physics & Methods**

LIST SUB-AREAS IN PORTFOLIO:

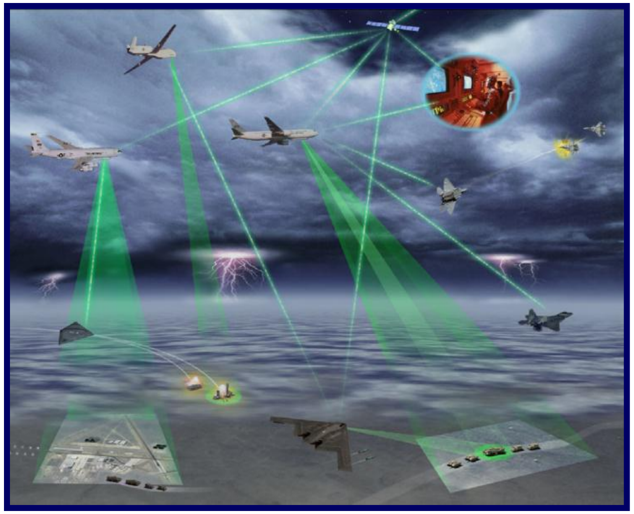


- **Heterogeneous Nanostructure Design & Synthesis**
  - interface lattice-strain & defect mitigation in III-V & II-VIs
  - energy band-edge alignment & barrier manipulation
- **EO/IR Photon - Micro/Nanostructures Interactions**
  - new materials, structures, physics, and phenomenology
  - novel photon-property transduction physics & methods
- **Novel Mixed-Mode Detector Design, Physics, Methods**
  - adaptive spectral & polarimetric filters & tuning schemes
  - embedded adaptive broadband absorption approaches
  - embedded conductive conduits, transparent interconnects
- **Optical/Electric μ-Cooling, 3-D Memory/Exploitation, Solar PV**

Motivation

Support Emerging Info-in-War Revolution:

- **THREATS HAVE CHANGED → dispersed & elusive enemy**
- **Near-real-time full situational awareness of threats is paramount to maintain asymmetric advantage.**
- **Increased reliance on autonomous ISR platforms.**
- **Present com-links & exploitation methods and resources are struggling to keep up…**



Zac Lemnios

"our warfighters are swimming in sensors but drowning in data – proliferation of sensors and large data sets are overwhelming analysts, who lack the tools to efficiently process, retrieve, store, and analyze vast amounts of data"

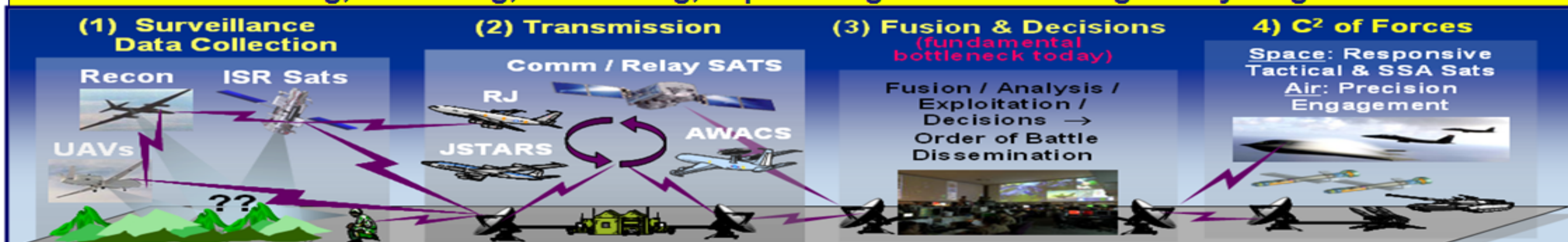
"data-to-decisions, cyber and autonomy are three of the seven stratefic science & technology priorities for the Department"

Testimony of The Honorable Zachary J. Lemnios
Assistant Secretary of Defense for Research and Engineering (ASD(R&E))
Before the United States House of Representatives Committee on Armed Services
Subcommittee on Emerging Threats and Capabilities
March 1, 2011

Sensor Data Explosion…

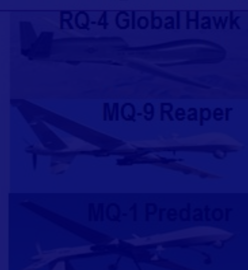
more global hot spots → greater ISR needs → more sensor data → DoD com bandwidth & exploitation bottlenecks

ISR Enables Tasking, Collecting, Processing, Exploitating & Disseminating Timely Target & Scene Data



$t_{'KILL'} = t_{find} + t_{fix} + t_{track} + (t_{COM}) + (t_{EXPLOIT}) + t_{target} + t_{engage} + t_{assess}$ ~ goal is single digit minutes

USAF RPA ISR Platforms: sensor packages include multi-spectral imagers, HD color & IR flowing video, laser designators, synthetic aperture radar, gnd moving target indicators…



Tremendous ramp-up of UAS systems is planned - 'nano,' 'micro,' 'man-portable,' 'air-launched,' 'multi-mission'

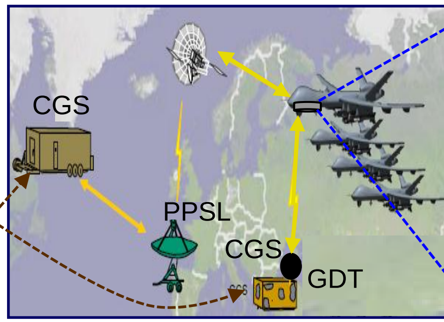
… Entirely new classes of detectors are needed:

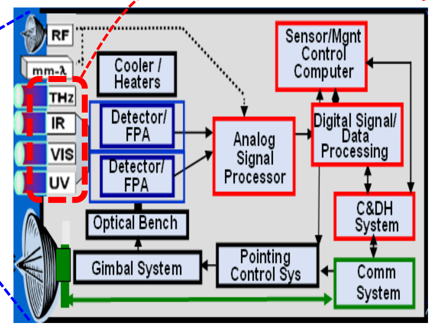
→ smarter, more capable, compact, affordable

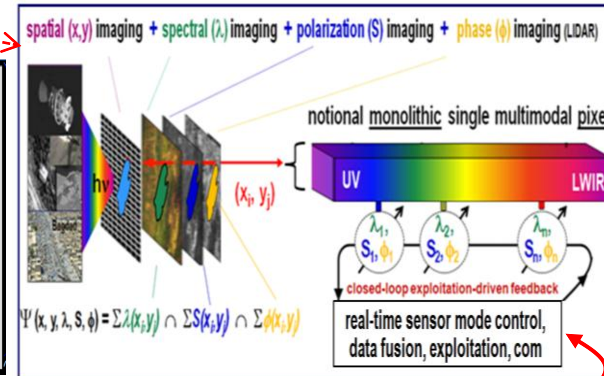
→ REAL-TIME ADAPTIVE SENSING would reduce data/com bottlenecks!

Real-Time Adaptive Sensing Can Quicken the Kill-Chain

Provide RPA *Sensor-Operators*/analysts vastly greater flexibility (<u>knobs to turn in REAL-TIME</u>) in choosing optimum sets of EO/IR sensor data to sense, collect & transmit.





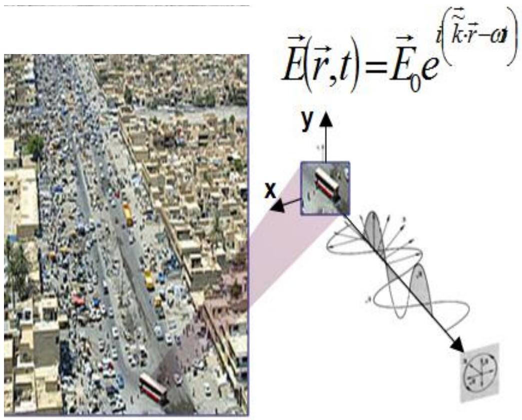


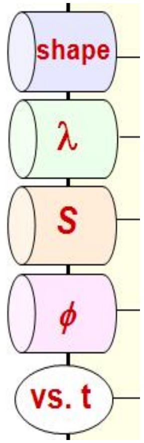
CGS + onboard-autonomy <u>control</u>

- <u>Real-time</u> optimum selection of perfectly registered spatial, spectral, polarimetric, phase signatures for a given scene to dramatically increase decision speed and accuracy.
- Trained operators (would) know the most probable 'layers' (modes) of sensor data to query in a given scene to achieve a specific knowledge objective – including which specific elements in the scene (pixel location) to collect, stamp, encrypt and forward – → could dramatically reduce onboard processing & com bandwidth needs for the feed.
- <u>EXAMPLES</u>:
  <u>Real-time tuning</u> of EO/IR (UV-IR in space) spectral bands to optimally filter dynamic-clutter for enhance target-scene contrast → REAL-TIME target discrimination, ID confidence, & extended range
  <u>Real-time tuning</u> of 5-10 EO/IR spectral bands for REAL-TIME optimized of temp/shape profiling and reflectance spectra for unique materials and subject identification.
  <u>Real-time selection</u> of wavelengths for polarimetric measurements for REAL-TIME surface feature contrast and discrimination of natural versus manmade objects

Great! So where can we find one of these magical Real-Time Adaptive sensors?

Sensing Modes





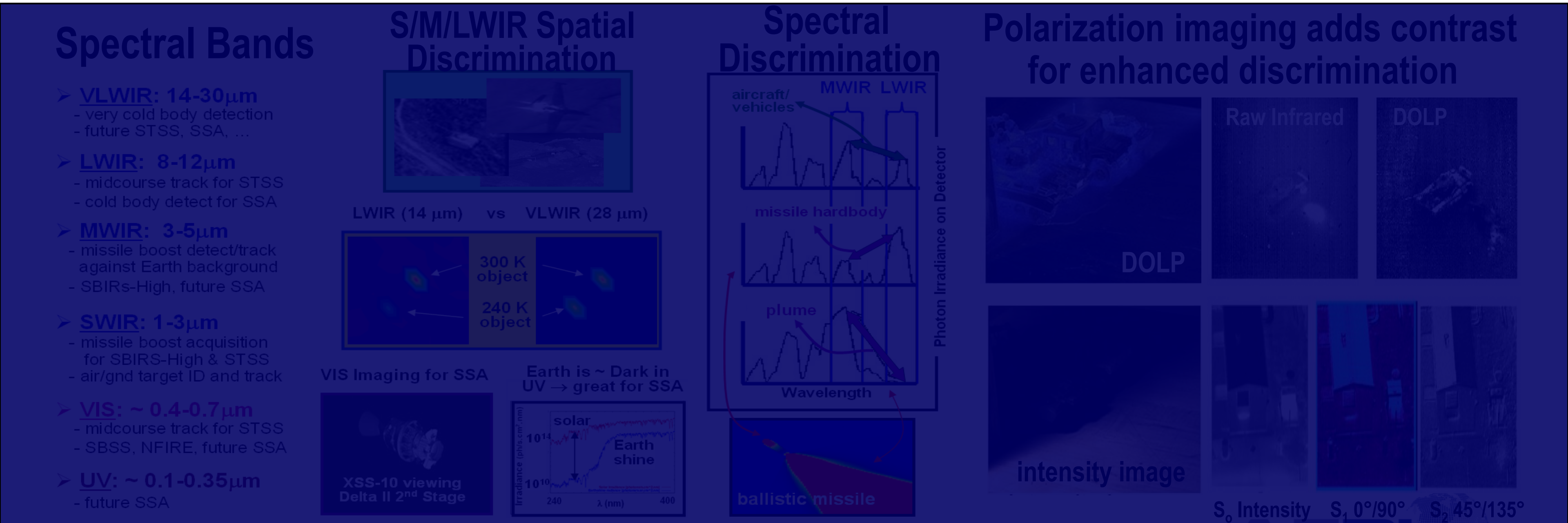
Spatial (imaging): shape, internal features, context, range profile

Spectral (wavelength): materials characteristics & phenomenology

Polarization: shape, surface roughness, natural vs. manmade

Phase: 3D shape, interferometry

Time (temporal): motion, dynamics, vibration



6.1 Opportunities in Real-Time Adaptive Sensing

A Multitude of Fundamental Materials Science & Device Physics Challenges & Opportunities

- Sensor (FPA) mode agility/addressability (pixel location, multiple wavelengths, polarization) + compactness + affordability → vertically integrated-monolithic device constructs
- Must innovate integrated-multi-functional structures & new interactions/transduction methods

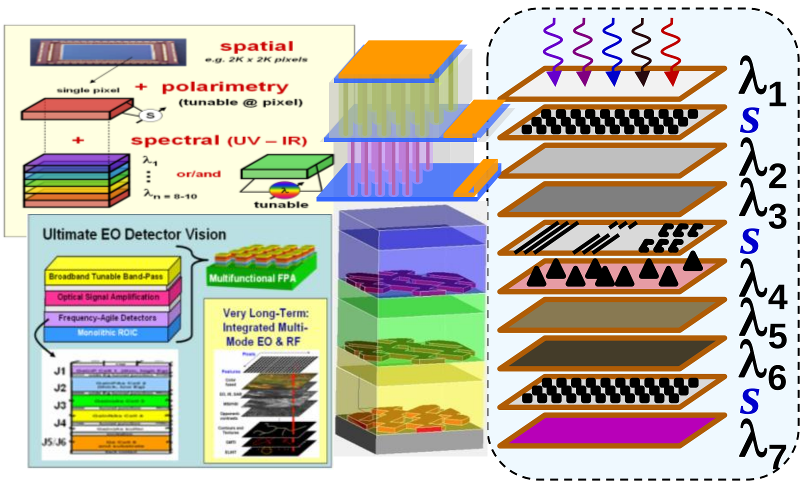
Desired New Functional Capabilities

(a) integrated sense-modes (r, λ, S, ϕ vs. t)

(b) vertically-aligned (boresight) modes

(c) real-time mode addressing, tune & read

(d) … the holygrail: $\int[(a) + (b) + (c)]dt$



Key Scientific Challenges

(for which no suitable solutions currently exist)

- **Heterogeneous Matl's Integration**
  - novel strain mitigation methods
  - band-edge alignment manipulation
  - nano-structure interface compliancy
- **Novel Dynamic Sensing Methods**
  - dynamic mat'l & device property tuning: band-gap, abs. coef., carrier transport, low-D structure energy levels, N_{ss}, etc.
  - 'functionalized' nano-structures
- **Novel Interconnect Schemes**
  - grp II-thru-VI-based transparent (UV-IR) films & electronics → reconfigurable
  - embedded 3-D transport conduits & adaptive switching schemes; color & absorption-rate sensitive 'functions'

Novel Sensing Structures & Methods

A Multitude of Fundamental Materials Science & Device Physics Challenges & Opportunities

unsolved, important, potentially breakthrough technical problems

6.1+

revolutionary C4ISR capability opportunities

6.1-

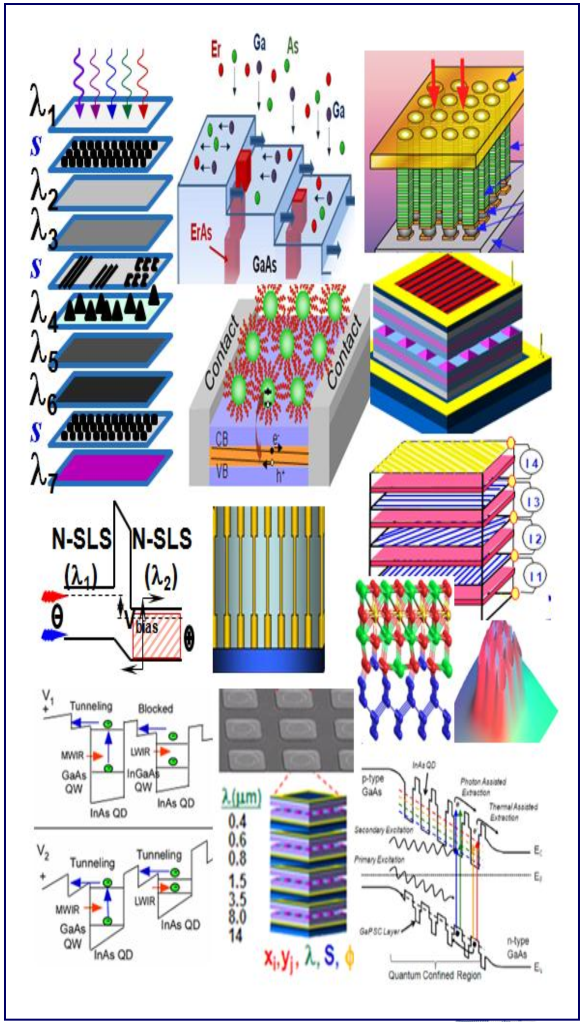
the 'what-if' opportunity driven, potential game-changing pay-offs

Desired 'Functional' Breakthroughs

(A) epi/sub mismatch strain mitigation methods
(B) epi-dislocation blocking barriers
(C) band-edge alignment manipulation
(D) dynamic bandgap/absorption-edge tuning
(E) dynamic optical absorption-depth tailoring
(F) dynamic wavelength & polarization filters
(G) photon property-matter transduction methods
(H) 3-D transparent pixel interconnects/conduits

Scientific Opportunities & Potential Enablers

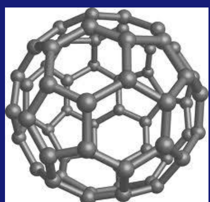
(1) carbon nanotubes: (A)-(H)
(2) coaxial nanorods: (A)-(H)
(3) core-shell nanocrystals: (A)-(H)
(4) Q-dots / wires / wells: (A)-(G)
(5) metamaterial structures (D)-(G)
(6) functionalized (1-4) nanostructures: (A)-(H)
(7) plasmonic structures & methods: (A)-(G)
(8) novel transparent thin-film synthesis: (D)-(H)
(9) compliant heterointerface methods: (A)-(C)
(10) combinations & integration of (1)-(8): (A)-(H)

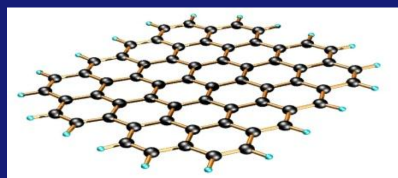


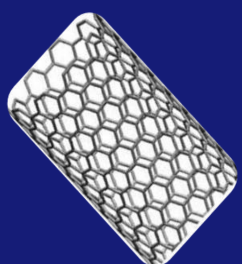
Diamond Nanowires – an accidental discovery

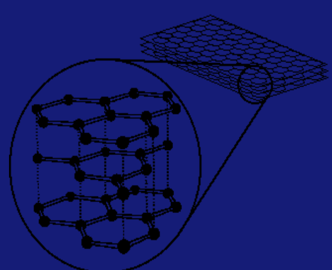
Jimmy Xu (Brown University)

All the fun discoveries in Carbon





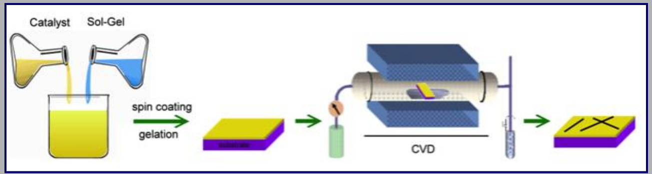


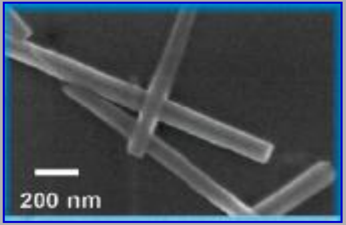


- all experimentally discovered -

- all forms on sp2 bond side -

Accidental discovery of diamond <u>nanowires</u> – grown in CVD





- **Crystallography checked!**
- **Raman spectroscopy checked!**
- **e^- energy loss spectroscopy √**

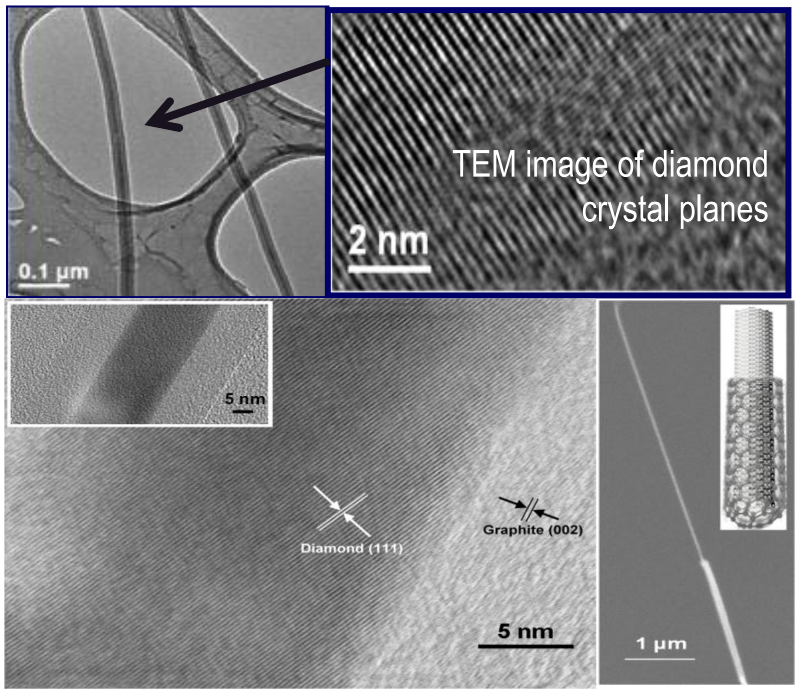
<u>IT ALL CHECKED OUT!</u>

- **First found in 2008 - 1 atm and 900C.**
- **Did not know beforehand.**
- **Did not know the growth mechanism, <u>still don't know</u>.**
- **Worse - could not reproduce it for 3 yrs !**
- **Eventually decided to publish in Nano Lett 2010.**

Diamond Nanowires – an accidental discovery

Jimmy Xu (Brown University)

… then on Nov 11th, 2011, after 100's of trials in 2 CVD reactors… reproducible Diamond Nanowires!



Invited Feature Article in "Nanoscale" of RSC (Royal Society of Chemistry) 2012

Potential Applications

Superior single-photon source vs. CNTs. Another spectral peak at 415nm, even brighter, stable at room temperature, achieved in 2011.

→ new options for high-speed computing, advanced imaging & secure communication.

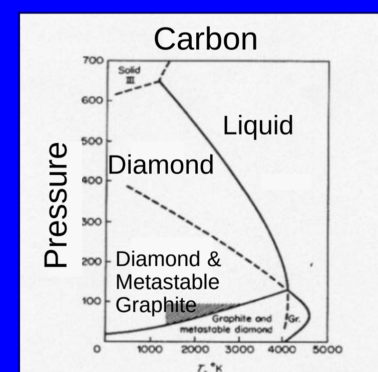
EO/IR Sensing applications -- potentially

→ tunable absorbers & current conduction conduits

→ patterned elements for adaptive thin-film spectral and polarization filters and modulators

Open Questions:

- Does physics allow the growth of diamond nanowires under atmosphere pressure & 900C?
- Was the well-established graphite-diamond phase transition condition wrong?



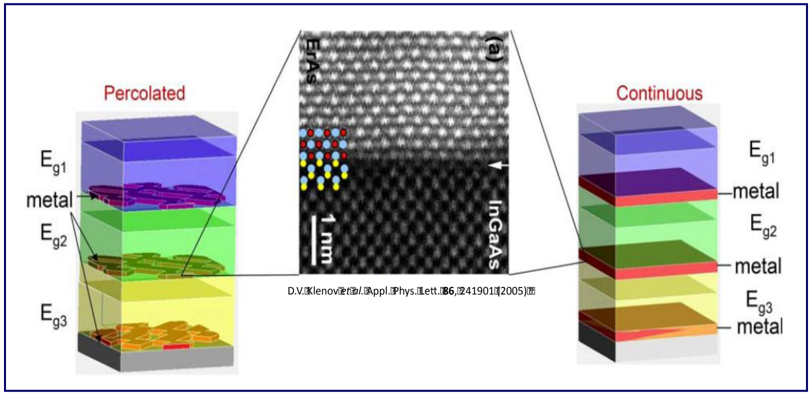
F. P. Bundy, et al., vol. 176, Nature, 1955, p. 51.

Multi-Phase III-V Nanocrystals
- A New Generation of Electronic Materials -

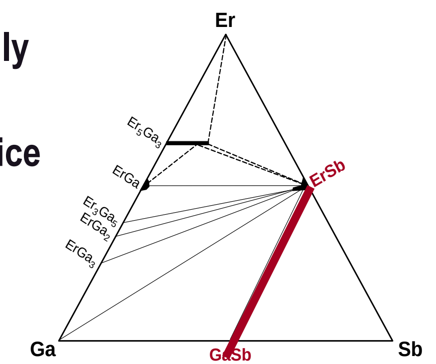
Chris Palmstrom (UCSB)

Science: understand & exploit novel formation methods $Ga_xEr_{1-x}Sb$ nanowires in GaAs; growth condition dependencies of $Ga_xEr_{1-x}Sb$ nanostructure geometry, optical & electrical properties.

Novel Monolithic Heterogeneous Structures

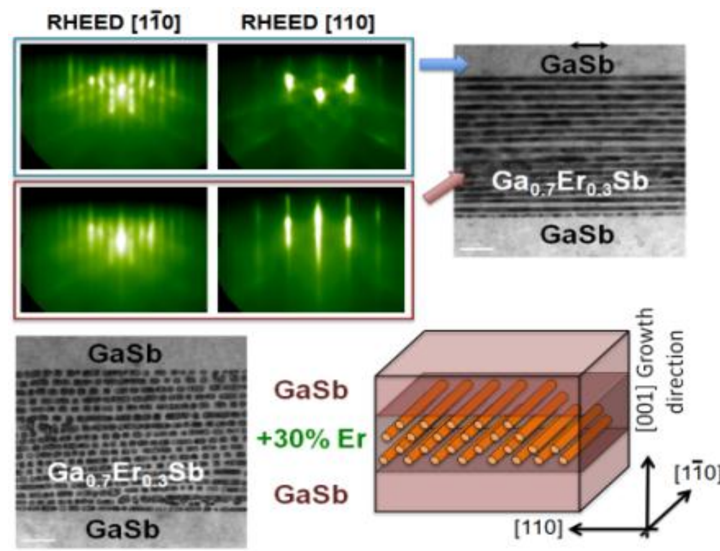


- RE-V's are thermodynamically stable with III-V's
- Share a common *fcc* sublattice
- Layers are semimetallic
- Growth of III-V epitaxiall overlayers over percolated layers of RE-V layers



A. Guivarc'h *et al.*, J. Mater. Res. B. 10, 1942 (1995)

Embedding high concentrations of epitaxial $Ga_xEr_{1-x}Sb$ nano-structures in GaAs



Phys. Rev. Lett. 107, 036806, July 2011

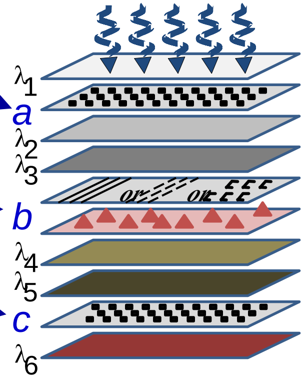
J. Vac. Sci. Tech. B 29(3) May/Jun 2011

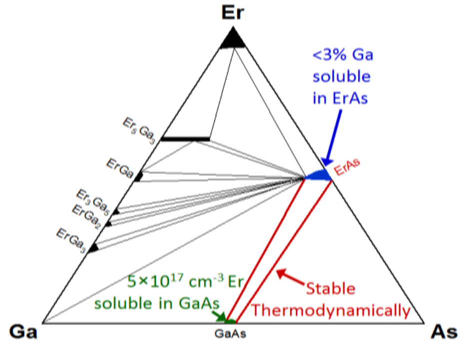
Embedded Ordered ErAs Metal Nanostructures

Seth Bank (UT Austin)

Scientific Problem: Innovative novel methods for epitaxial semimetallic ErAs nanostructures/films in III-V stacks without degrading III-V layers grown above.

Epitaxial Metallic NanoStructures & Films

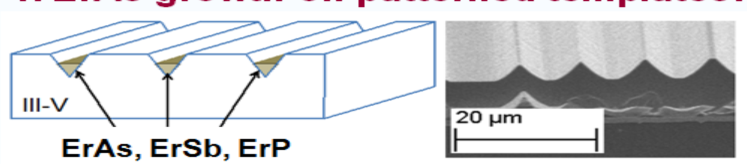




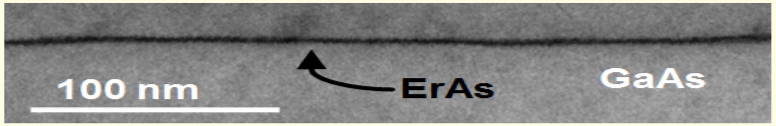
Députier et al., J. Alloys & Comp. **202**, 95 (1993)

Approach:

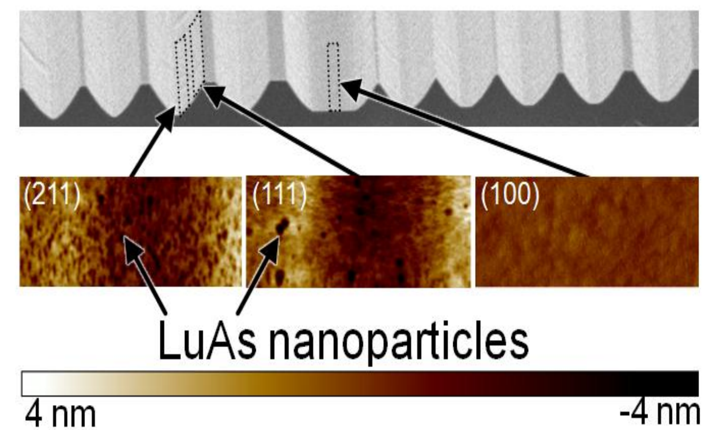
1. ErAs growth on patterned templates:



2. Embedded film growth method:



Developed Templated Regrowth

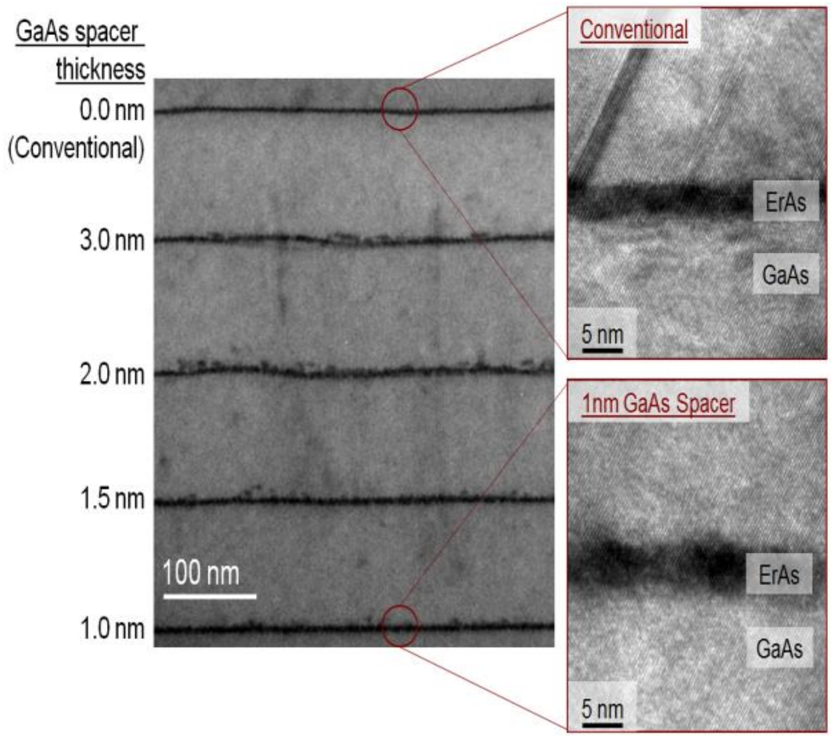


- *in situ* atomic hydrogen clean prior to regrowth:
  - No contaminants evident in MBE
  - PL comparable for structures grown before & after regrowth
- AFM: nanoparticle size & density vary based on surface orientation
  - Preferential LuAs growth on (111) and (211) planes
  - Signature of LuAs similar to AFM expts of ErAs on (100) GaAs

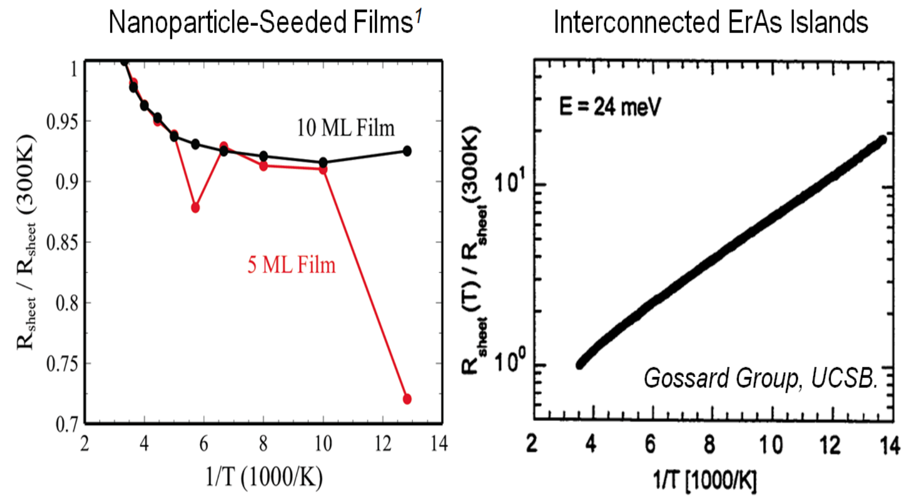
Embedded Ordered ErAs Metal Nanostructures

Seth Bank (UT Austin)

Novel Embedded Patterned Films



Embedded Film Characteristics



- Temperature-dependent conductivity
  - Films exhibit band-like transport
  - Distinct from thermally-activated hopping for interconnected islands

Films are continuous and suitable for buried contacts, conduits, and multifunctional patterned structures.

S.R. Bank et al., "Surface segregation effects of erbium in GaAs growth and their implications for optical devices containing ErAs nanostructures," *Appl. Phys. Lett.*, vol. 98, pp. 121108-1-3, March 2011.

S.R. Bank et al., "Suppression of Planar Defects in the Molecular Beam Epitaxy of GaAs/ErAs/GaAs Layered Heterostructures," *Appl. Phys. Lett.*, vol. 99, pp. 072120-1-3, Aug. 2011.

S.R. Bank et al., "Scanned Probe Characterization of Self-Assembled ErAs/GaAs Semimetal/Semiconductor Nanostructures Grown by Molecular Beam Epitaxy," *Appl. Phys. Lett.*, vol. 99, pp. 133114-1-3, Sept. 2011.

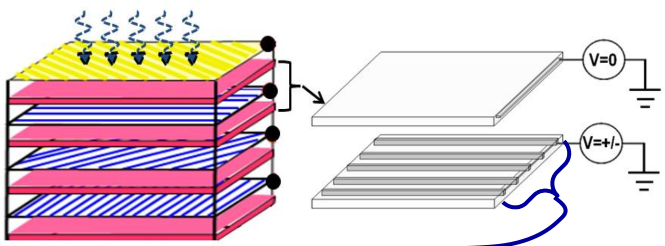
Lead Chalcogenide Nanorod Liquid Crystals

Joe Tischler & Janice E. Boercker (Navy Research Lab)

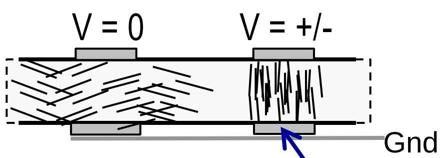
Science: innovate, understand, exploit synthesis of PbSe liquid crystals for polarization appl's

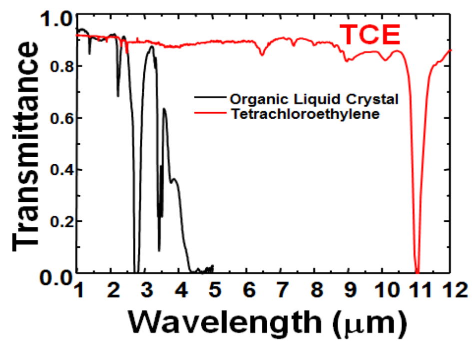
Vision: bias-tunable thin-film polarizers, modulators, filters

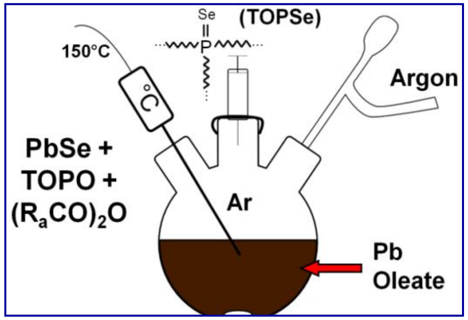
Approach: investigate viability of PbSe nanorod liquid crystals suspended in TCE – TCE transparent to 11μm.



potentially leverage



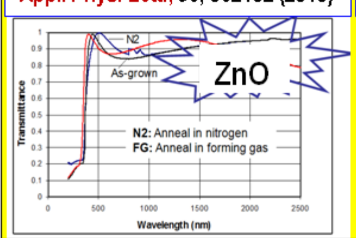


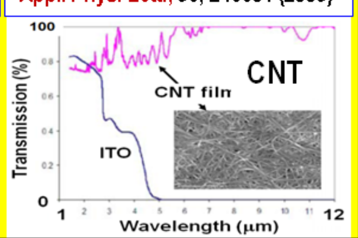


Successful AFOSR-sponsored transparent thin-film CNT & ZnO

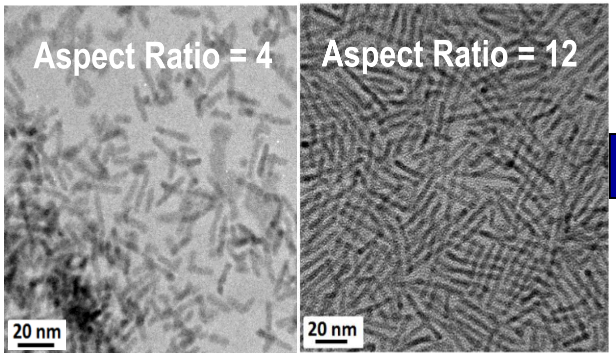
Burhan B.(AFRL/RY) — Appl. Phys. Lett., 96, 062102 (2010)

Xuejun Lu (UMass Lowell) — Appl. Phys. Lett., 93, 243301 (2009)

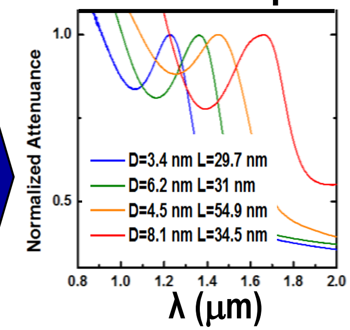




Increased nanorod density and aspect ratio: 4 →12

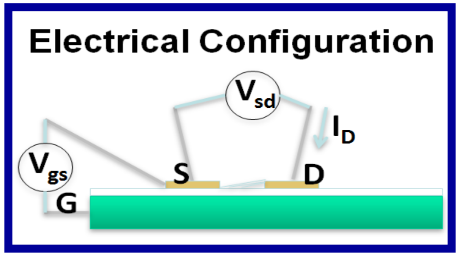


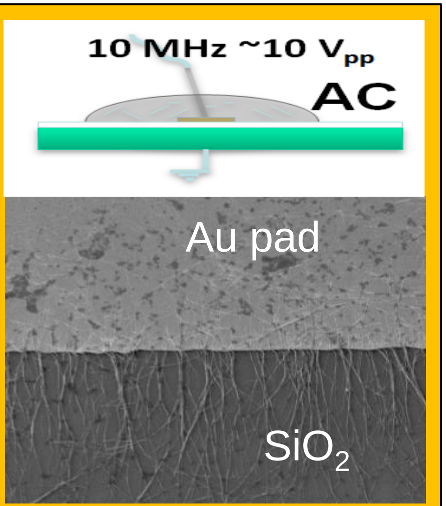
Increased bandgap from to 1.0-2.0 μm



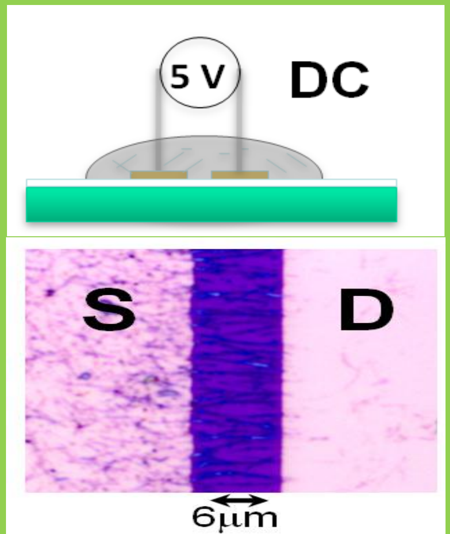
Lead Chalcogenide Nanorod Liquid Crystals

Joe Tischler & Janice E. Boercker (Navy Research Lab)

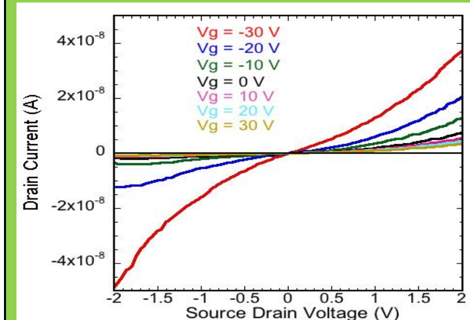




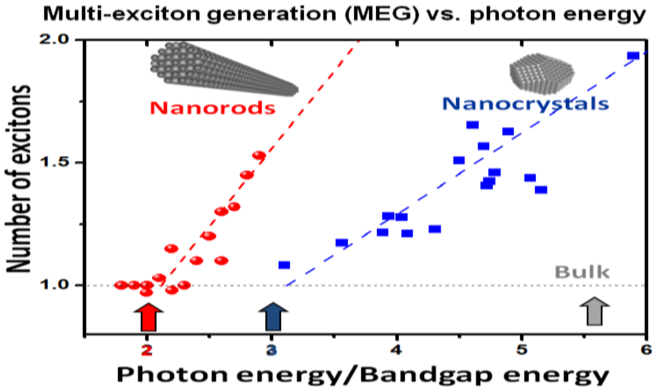
Alignment occurs between contact and substrate, not the neighboring contact.

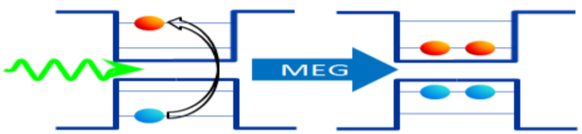


Alignment occurs between contacts



new theoretical and physical understandings





Current optoelectronic technology limited by one exciton per photon (energy lost in heat)

Nanorods have enhanced MEG as compared to nanocrystals

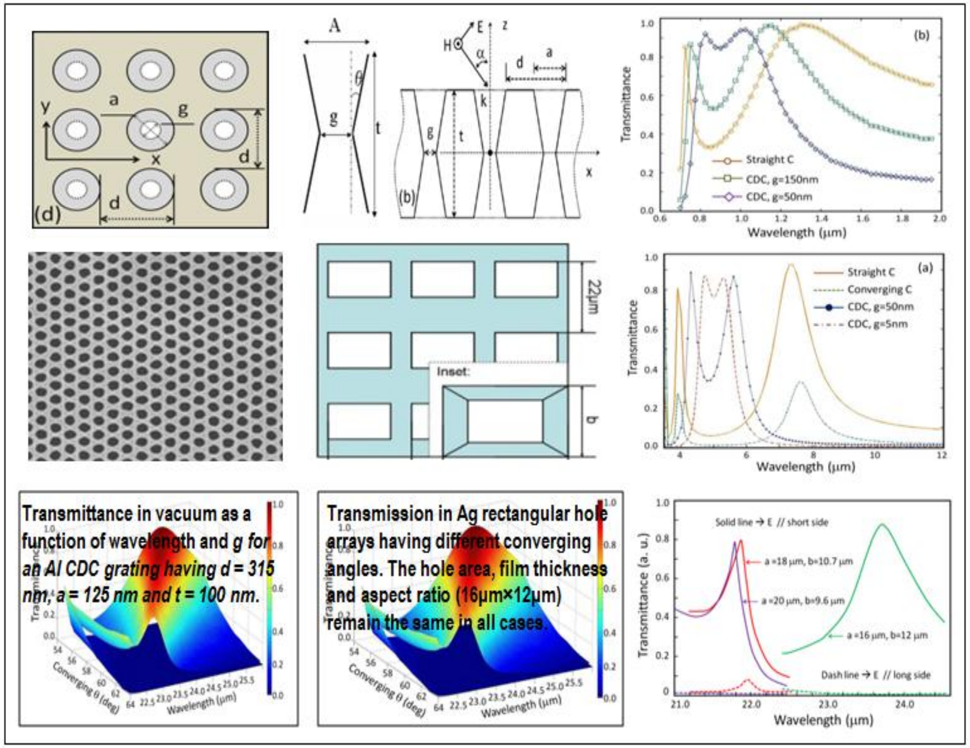
Nanorods have 10X higher absorption coefficients than nanocrystals

Nano Letters 11, 3476 (2011); *J. Phys. Chem. Lett.* 2, 527 (2011); *J. Mater. Chem.* 21, 2616 (2011)

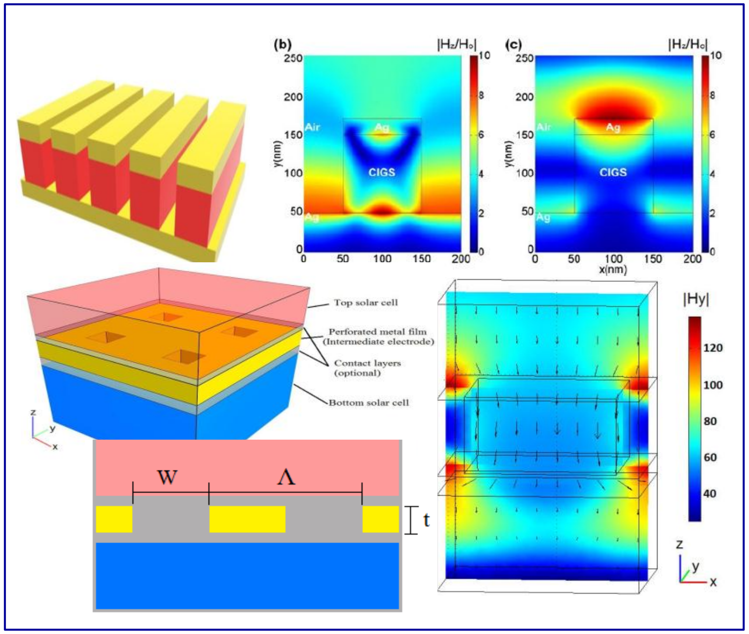
Novel Periodic Nanostructures and Apertures for Multifunctional EO-RF Tuning

Yalin Lu (USAF Academy)

Tunable transmission, enhanced emission and modulation in ordered metallic nanostructures having varying channel shape; selective enhanced photon absorption and carrier generation in novel solar cells structures:
→ Tailored effects via localized plasmonic resonance, Fabry-Perot cavity resonance, waveguiding, antenna effects, etc.



<u>Novel PV Cells</u>: selective photogeneration and photocurrent enhancements of 30-50%



‘Tunable Transmission & Enhanced Emission in Ordered Metallic Nanostructures Having Varying Channel Shape’, Yalin Lu, Applied Physics A, 103, 597 (2011)
‘Enhanced photon absorption and carrier generation in nanowire solar cells’, Y. Lu et al., Optics Express, Vol. 20, Issue 4, pp. 3733-3743 (2012)
‘Adding a thin metallic layer to silicon thin film solar cells’, Y. Lu et al., Physica Status Solidi (c), 8, 843 (2011)
‘Microstructured silicon created with a nanosecond neodymium-doped yttrium aluminum garnet laser’, Y. Lu et al., Appl. Phys. A, 104, 755 (2011)
‘Enhanced Absorption in Si Solar Cells via Adding Thin Surface Plasmonic Layers & Surface Microstructures’, Y. Lu et al., PIERs Online, 7, 331 (2011

Breakthrough Carrier Lifetimes in Type-II Superlattice (T2SL) IR Photodetectors for Increased Temp Operation

Yong-Hang Zhang (ASU) - jointly supported by **ARO MURI (Bill Clark)**

Carrier lifetime in LWIR T2SL improved by 13 times from ~30 ns to 412 ns !!

Carrier lifetime for **Ga-free InAs/InAsSb type-II superlattice of 412 ns** was achieved

→ within the same order of magnitude of the reported record for **HgCdTe (1 μs)**

→ **could potentially lead to background limited T2SL MWIR-LWIR (3-12μm) performance higher operating higher temperatures than HgCdTe !**

Detailed calculations in mid 90's predicted advantages of T2SLs

T2SLS detectors offer potential for:

- **larger effective mass than HgCdTe for the equiv. E_g → less band-to-band tunneling**
- **suppressed Auger recombination in both the conduction & valence bands; generation & recombination can be reduced w/wider E_g's.**

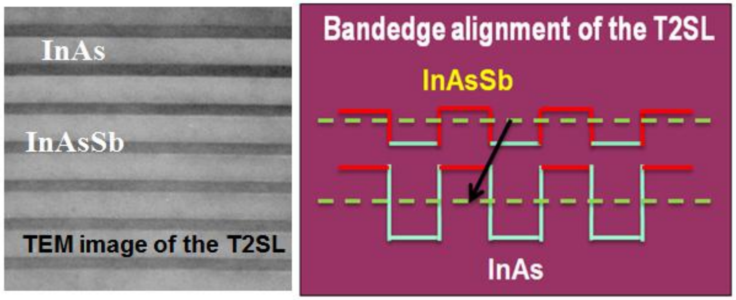
However, the predicted enhanced lifetimes in T2SLs have eluded the community, until now.

	MCT	QWIP	T2SL	
			InAs/InGaSb	InAs/InAsSb
Performance	High	Low	High/medium	High
QE	60%	5-8%	60%	>60%
Dark current	High	Very high	Low	Low
Material Uniformity	Poor	High	High	High
Wafer size	Small	Largest	Large	Large
Wavelength range	Wide (MWIR and LWIR)	Narrower (LWIR)	Wide (MWIR and LWIR)	Wide (MWIR and LWIR)
Wavelength Uniformity	Poor	Good	Good	Good
Detection bandwidth	Broad	Narrow	Broad	Broad
Cost	High	Very low	Low	Low

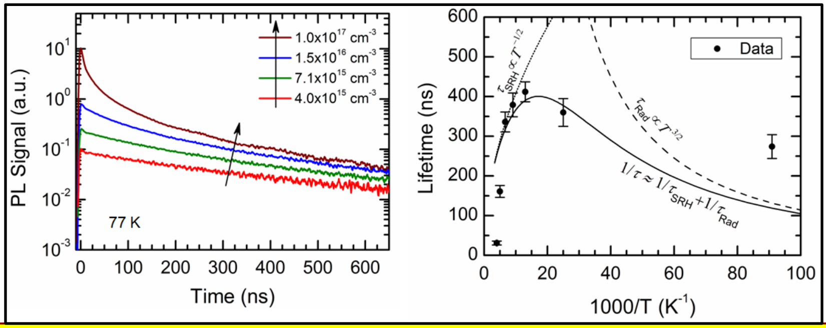
Breakthrough Carrier Lifetimes in T2SL Detectors

Yong-Hang Zhang (ASU) - jointly supported by **ARO MURI (Bill Clark)**

How did they do it?* → *replaced Ga in conventional InAs/InGaSb T2SL with As → InAs/InAsSb

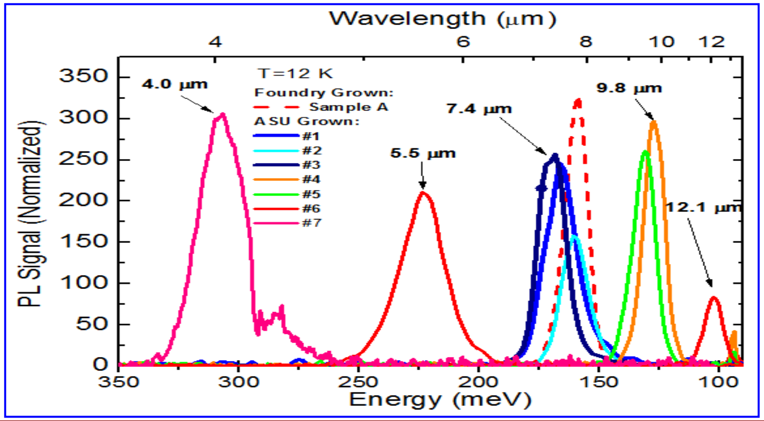


Breakthrough InAs/InAsSb T2SL Carrier Lifetimes



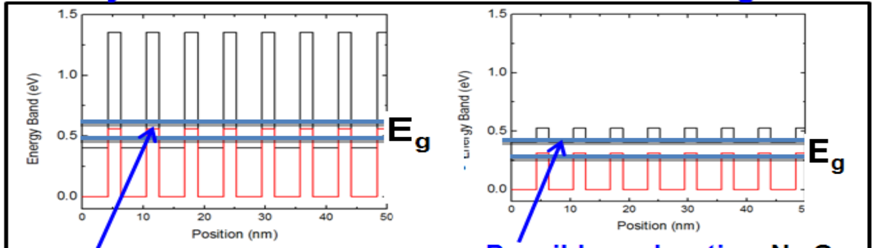
Y. H. Zhang et al., Appl. Phys. Lett. 99, 251110 (2011)

PL Intensity Comparison Between ASU Grown AsInAs/InAsSb and State-of-theArt InAs/InGaSb Grown by an Industry Vendor



Y. H. Zhang et al., SPIE Defense and Security, Apr 2012

Why is carrier lifetime in Ga-free T2SL longer?



Possible explanation: The energy level of Ga related broken bonds are possible in the middle of the energy gap, causing SRH recombination traps.

Possible explanation: No Ga related bond. The energy level of In related broken bonds are in the conduction band, minimizing the SRH recombination traps.

Novel Interband Cascade IR Photodetector (ICIP)

Rui Yang (U. of Oklahoma)

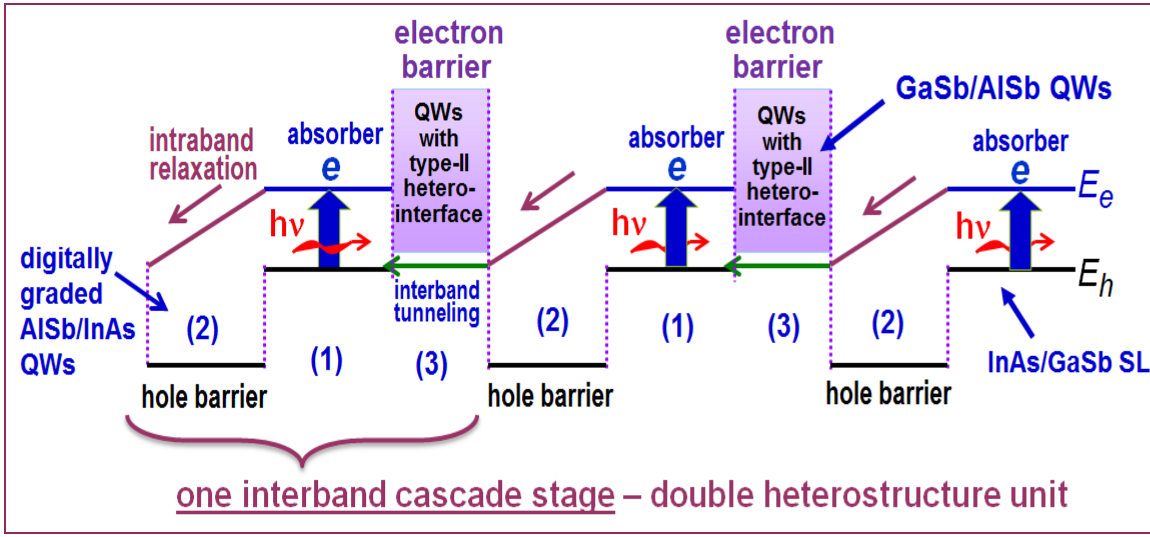
Innovation: novel quantum-engineered interband cascade (IC) structures for near room temp mid-IR detector operation → ultra-low dark currents - detectivity close to 10^{10} Jones or higher.

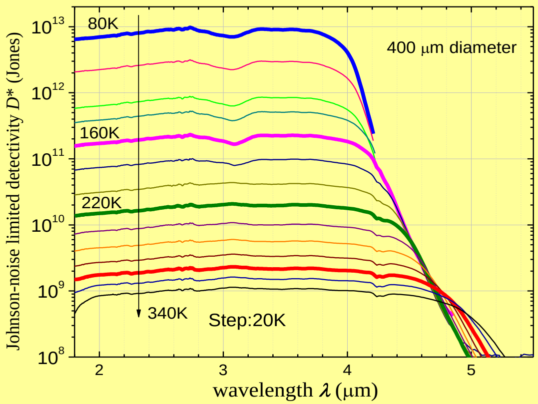
Jan 2012

JOURNAL OF APPLIED PHYSICS 111, 024510 (2012)

Interband cascade infrared photodetectors with enhanced electron barriers and *p*-type superlattice absorbers

Z. Tian,[1,a)] R. T. Hinkey,[1,2] Rui Q. Yang,[1,a)] D. Lubyshev,[3] Y. Qiu,[3] J. M. Fastenau,[3] W. K. Liu,[3] and M. B. Johnson[2]
[1]School of Electrical and Computer Engineering, University of Oklahoma, Norman, Oklahoma 73019, USA
[2]Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma 73019, USA
[3]IQE Inc., Bethlehem, Pennsylvania 18015, USA





The Johnson-noise limited detectivity (D^*) exceeding 10^{12}, 10^{11}, 10^{10}, 10^{9} Jones at 80, 160, 230, 300 K, respectively.

Key Features of ICIPs:

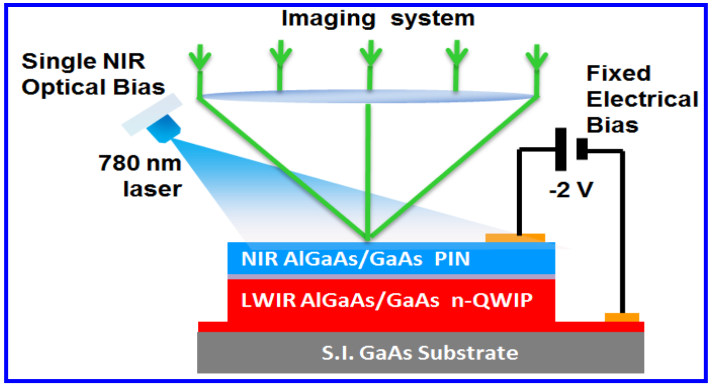
- Conventional depletion region is eliminated → suppression of SRH gen-current
- Discrete architecture → signal to noise ratio $S/N \propto 1/N_a^{1/2}$ (N_a: No. of absorbers) → circumvent the diffusion length limitation → high absorption QE
- Photo-carriers move over a short distance, i.e. one stage → fast response → viable for high-speed devices: lasers-free-space com & heterodyne detection

Novel Tunable NIR/LWIR Photodetector

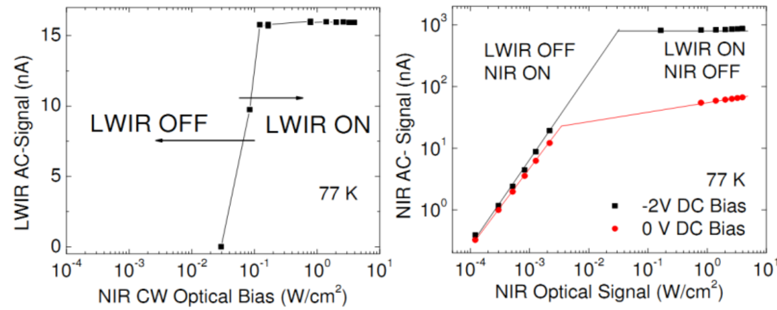
Yong-Hang Zhang (ASU) – with joint support from **ARO**

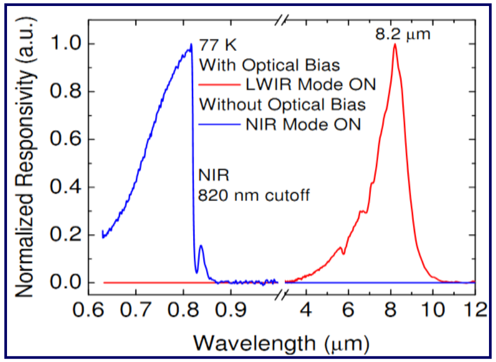
2-Terminal Dual-Band IR Detector

NIR/LWIR optical addressing demonstrated for the first time…



- A 2-band photodetector consisting of NIR, PIN, LWIR & QWIP was demonstrated.
- The device is compatible with *low-cost* standard ROICs for two-terminal FPA.





Y.H. Zhang, "Optically-Addressed Multiband Photodetector for Infrared Imaging Applications," Proc. of SPIE Vol. 8268, Jan 2012

Other Pioneering Work Underway on Grant

- 3-color photodetectors using NIR PIN, MWIR QWIP and LWIR QWIP.
- 4-color InAs/InAsSb T2SL photo-detectors in MWIR and LWIR ranges.
- **UV to IR multi-color photodetectors using 6.1 Å II-VI and III-V materials.**

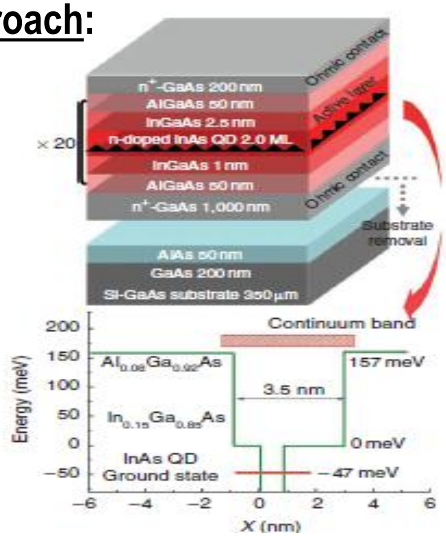
Novel Plasmonic Focal Plane Array

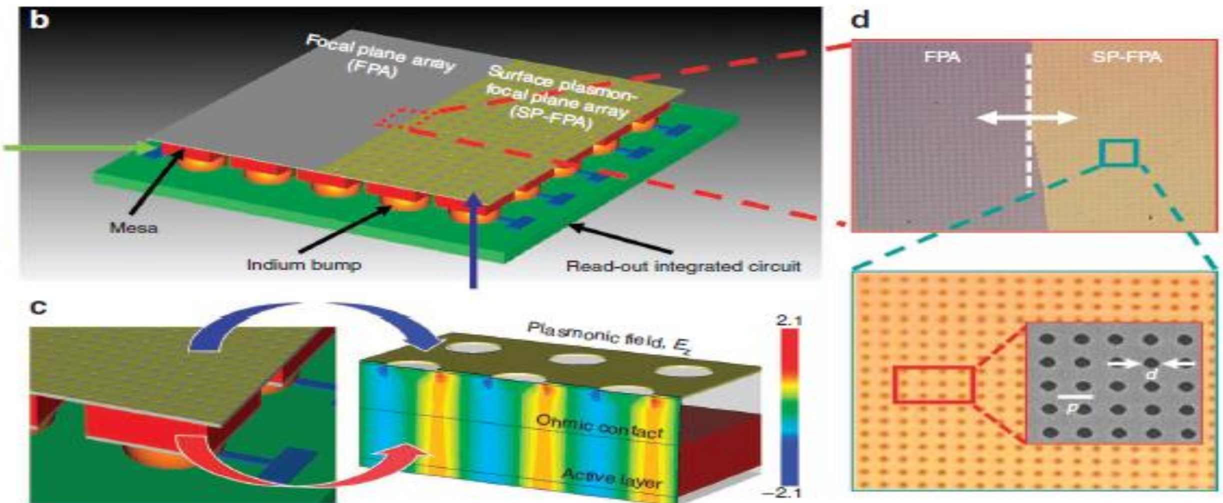
THE UNIVERSITY of NEW MEXICO

Sanjay Krishna (U. of New Mexico)

Innovation: 1st focal plan array (256x320) with integrated plasmonic resonators → 160% enhancement!

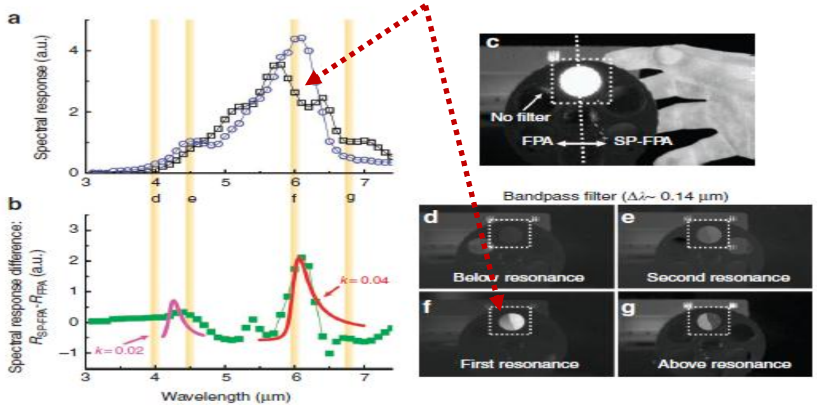
Approach:





Results:

Plasmonic Enhancement




nature COMMUNICATIONS

ARTICLE

Received 5 Jan 2011 | Accepted 17 Mar 2011 | Published 19 Apr 2011

DOI: 10.1038/ncomms1283

A monolithically integrated plasmonic infrared quantum dot camera

Sang Jun Lee[1,*], Zahyun Ku[2,*,†], Ajit Barve[2], John Montoya[2], Woo-Yong Jang[2], S.R.J. Brueck[2], Mani Sundaram[3], Axel Reisinger[3], Sanjay Krishna[2] & Sam Kyu Noh[1]

… Raytheon has expressed strong interest in transitioning into their next generation (4th) detectors!

AFRL

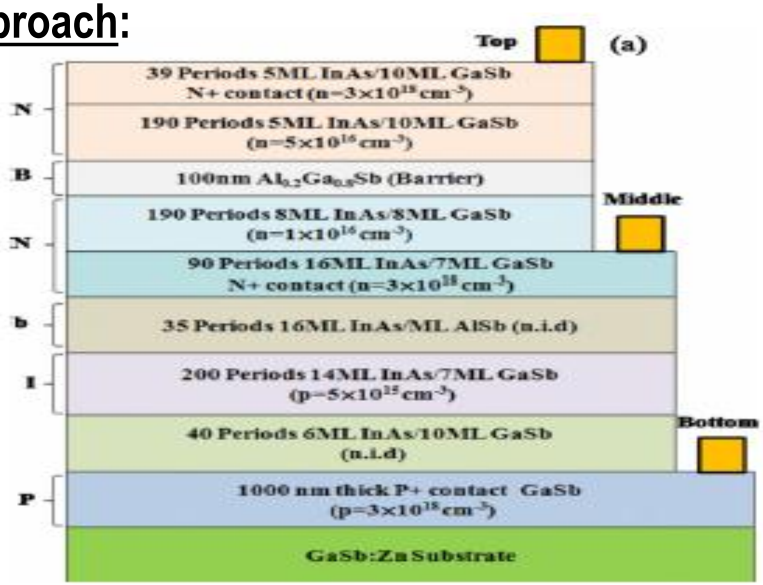
Three Color InAs/GaSb Superlattice IR Detector

THE UNIVERSITY of NEW MEXICO

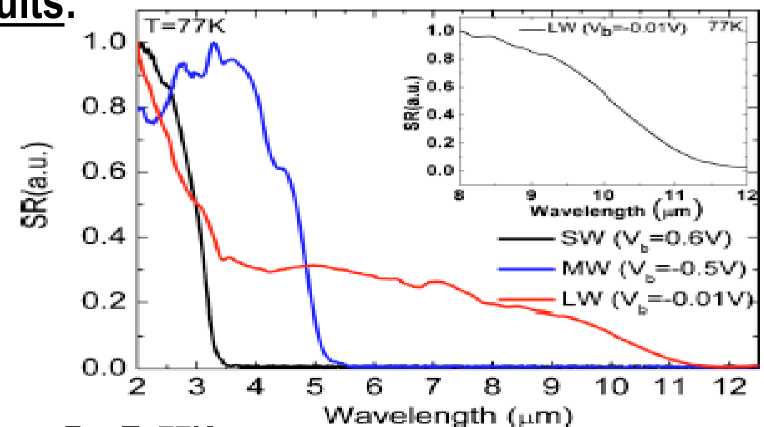
Sanjay Krishna (U. of New Mexico)

Innovation: 1st 3-terminal detector pixel implementing unipolar nBn/PbIbN architecture

Approach:



Results:



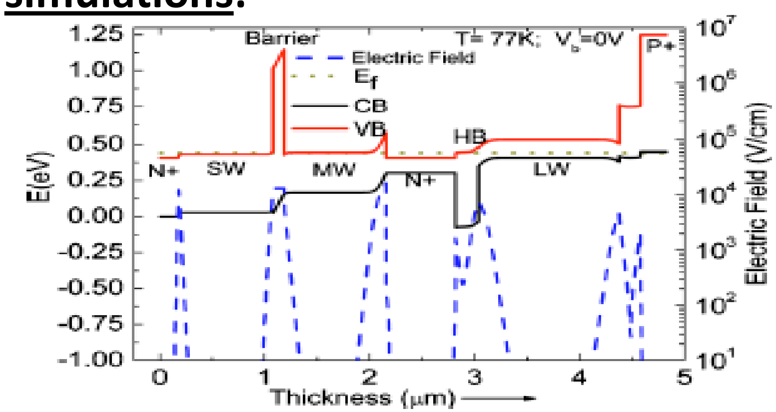
For T=77K:

SWIR at V_b = +0.01V, D* = 1.8×10^{12} cmHz$^{1/2}$/W

MWIR at V_b = -0.3V, D* = 1.4×10^{11} cmHz$^{1/2}$/W

LWIR at V_b = -0.01V, D* = 9.9×10^{10} cmHz$^{1/2}$/W

simulations:



APPLIED PHYSICS LETTERS 98, 121106 (2011)

Three color infrared detector using InAs/GaSb superlattices with unipolar barriers

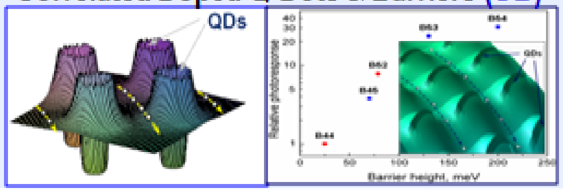
N. Gautam, M. Naydenkov, S. Myers, A. V. Barve, E. Plis, T. Rotter, L. R. Dawson, and S. Krishna[a]

Department of Electrical and Computer Engineering, Center for High Technology Materials, University of New Mexico, Albuquerque, New Mexico 87106, USA

AFRL

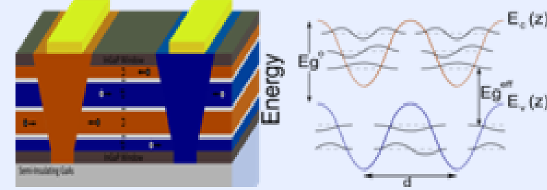
Other Portfolio Investments

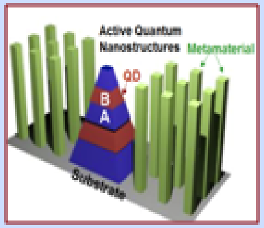
Electron Processes & Physics of Correlated Doped Q-Dots & Barriers (UB)



Doped Q-Dot PV Cells (ARL & UB)

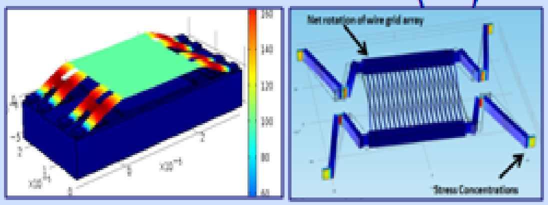
Novel Q-Dot nipi PV Cell (STTR w/RIT)



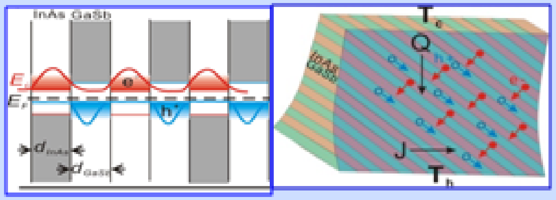


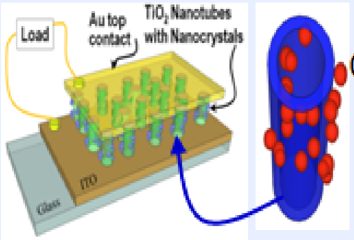
Nanotemplate-Enabled Highly-Heterogeneous Q-Nanostructure & Metamaterials Systems (USC)

Tunable MEMs for Δ λ & S (RIT)

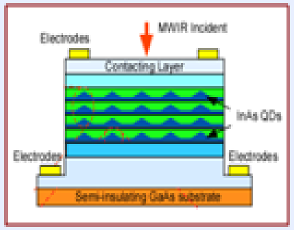


Peltier Cooling (Northwestern U.)



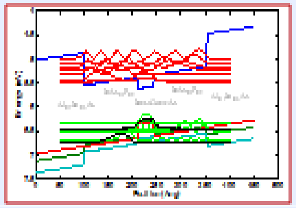


Functionalizing Coupled Nanorods, Nanotubes and Core/Shell Nanocrystals (U. Arkanas)

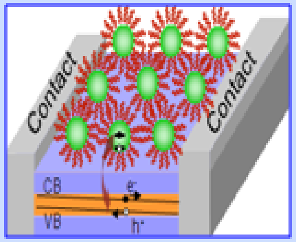


IR-Transparent CNT Membrane-based Tunable Spectral Filters (U. Mass Lowell)

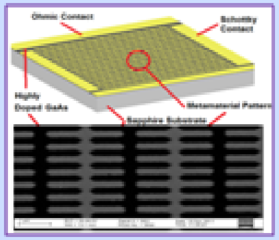
Ridge-Waveguide Laser Cooling



...based on novel Q-well-Q-confined stark shifts... (Northwestern U.)

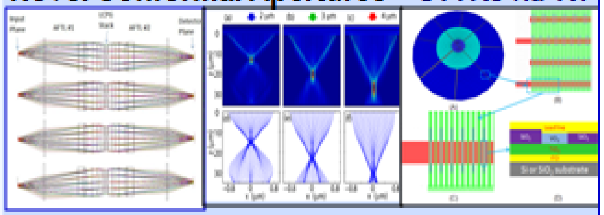


Non-Radiative Energy Transfer (NRET) Sensing via Q-Composite Structures (USC)



Monolithic Integrated Metamaterial-based Polarizer Grid (Tufts U.)

Novel Conformal Apertures – STTRs via RY



Coordination/Conferences/International

DoD Coordination:

- **ARO**: jointly fund efforts with ASU on novel detector materials science & device approaches
- **ARL**: support ARL in-house: novel Hg-based semiconductor epi-growth studies (Adelphi), collaboration with sensors group on doped Q-dot studies
- **NRL**: support in-house polarimetry filter research effort
- **DARPA**: coordinate w/Nibir Dhar in sensors -- their investments primarily 'applied' w/little 6.1
- **NSF**: follow nano-electronics investmnets, periodically attend reviews

Conferences/Workshops:

- SPIE DSS session organizer/speaker
- SPIE Photonics W. session organizer
- IEEE SISC: session organizer
- IEEE ICSC sponsor

International:

- National Cheng Kung University, Taiwan: CNTs
- Taras Shevchenko University, Kiev, Ukraine: polarimetry

Take Aways

- Portfolio targets crucial long-term USAF ISR capability needs.
- Strong thrusts established in multiple fundamental science challenge areas spanning novel solid-state nanomaterials and quantum structures synthesis, and breakthrough mixed-mode multi-discriminate sensor device concepts and methods.
- Good portfolio balance between theoretical and experimental research – most efforts include elements of both.
- Excellent progress achieved in novel heterogeneous nano-structures synthesis and integration, novel photon//detector materials interactions & phenomenology, and novel mixed-mode sensing device concepts and methods.